HUMANIZED ANTIBODY SPECIFIC FOR SURFACE ANTIGEN PRE-S1 OF HBV AND PREPARATION METHOD THEREOF

FIELD OF THE INVENTION

The present invention relates to humanized antibodies specific for HBV surface antigen pre-S1.

Particularly, this invention relates to humanized antibodies specific for HBV surface antigen pre-S1, the antibody comprising humanized heavy and light chain; to genes encoding the humanized heavy or light chain; to expression vectors containing said genes and *E. coli* transformants containing said expression vector; and to pharmaceutical composition comprising said humanized antibody, which may be administered in order to prevent HBV infection or to treat chronic hepatitis B.

BACKGROUND

HBV (Hepatitis B Virus) is responsible for chronic or acute human hepatitis that may get worse to liver cirrhosis or cancer. It is estimated that about three hundred million people are suffering from hepatitis in the world (Tiollais and Buendia, *Sci. Am.* 264:48, 1991).

There are three kinds of HBV surface proteins containing different sets of surface antigens. Particularly, these surface antigen proteins includes the Major Protein containing S antigen, the Middle

Protein containing S and pre-S2 antigens, and the Large Protein containing S, pre-S2 and pre-S1 antigens (Neurath and Kent, *Adv. Virus Res.*, 34:65-142, 1988). All the surface antigen proteins can induce antibodies that neutralize HBV, and especially, antibodies against HBV pre-S antigen are associated with the elimination of the virus and the recovery from HBV infection, overcoming non-responsiveness to the S antigen (Iwarson et al., *J. Med. Virol.*, 16:89-96, 1985; Itoh *et al.*, *Proc. Natl. Acad. Sci. USA*, 85:9174-9178, 1986; Budkowska *et al.*, *J. Med. Virol.*, 20:111-125, 1986; Milich *et al.*, *Proc. Natl. Acad. Sci. USA*, 82:8168-8172, 1985; Milich *et al.*, *J. Immunol.*, 137:315-322, 1986).

Unlike pre-S2 or S antigen, pre-S1 antigen is exclusively present in infectious virus particles (Heerman *et al.*, *J. Virol.*, 52:396-402, 1984) and involved in the infection into human liver cells. Thus, it has been reported that monoclonal antibody specific for pre-S1 antigen may efficiently neutralize HBV (Neurath *et al.*, *Cell*, 46:429, 1986; Pontisso *et al.*, *Virology*, 173:533, 1989; Neurath *et al.*, *Vaccine*, 7:234, 1989), and the monoclonal antibody is considered to be useful in the prevention of HBV infection and the treatment of chronic hepatitis B.

So far hepatitis B immunoglobulin has been employed as a preventive for HBV infection, which may

protect, for example, a newborn baby from a HBV-positive mother, medical personnel exposed to HBV, and liver transplant patient with chronic HBV-related liver disease (Beasley *et al.*, *Lancet*, 2:1099, 1983; Todo *et al.*, *Hepatology*, 13:619, 1991). However, hepatitis B immunoglobulin has some shortcomings such as its limited availability, low specific activity and its possible contamination with infectious agents. Furthermore, it is another disadvantage of hepatitis B immunoglobulin that blood plasma should be continuously supplied.

As an alternative for the hepatitis B immunoglobulin, mouse monoclonal antibodies against HBV surface antigens have been developed. Although the mouse monoclonal antibodies show high affinity for the antigen and can be prepared on a large scale, they induce human anti-mouse antibody response in patients (Shawler *et al.*, *J. Immunol.*, 135:1530, 1985). There were attempts to prepare human monoclonal antibodies, but few of these antibodies showed a high level of affinity.

Instead, humanized antibodies have been developed. Humanized antibody has a high level of affinity and specificity similar to mouse antibodies, whereas its immunogenicity is minimized. Humanized antibody is a hybrid antibody in which CDRs (Complementarity Determining Regions) of a mouse antibody is grafted to

a human antibody by genetic engineering technique. It can be easily prepared on a large scale, and hardly elicits immune responses in humans since most of the DNA sequences encoding the humanized antibodies are derived from a human DNA sequence (Riechman *et al.*, *Nature*, 332:323, 1988; Nakatani *et al.*, *Protein Engineering*, 7:435, 1994).

To overcome the aforementioned and other disadvantages of mouse or human HBV immunoglobulin, we, the inventors of the present invention, have attempted to prepare humanized antibodies which can be used to prevent HBV infection and to treat chronic hepatitis B. Prior to this invention, we prepared a mouse monoclonal antibody KR127 against HBV surface antigen pre-S1. Additionally, we isolated the genes encoding the heavy and light chain variable regions of KR127 antibody and determined the sequences of the genes (Korea Patent Application No. 1997-30696). The present invention is performed by selecting human immunoglobulin genes homologous to the sequences of KR127 antibody light chain and heavy chain variable regions; constructing the humanized antibody genes; inserting the genes into expression vectors; introducing the vectors into host cells; obtaining humanized antibodies from the culture of the transformed cells; and confirming that the humanized antibodies have high affinity to HBV pre-S1

antigen, similar to the mouse monoclonal antibody KR127.

SUMMARY OF THE INVENTION

It is an object of this invention to provide humanized antibodies specific for CDRs of mouse HBV surface antigen pre-S1, having high affinity to the antigen and reduced immunogenicity in human.

In accordance with the present invention, the foregoing objects and advantages are readily obtained.

The present invention provides humanized antibodies specific for HBV surface antigen pre-S1, comprising humanized heavy and light chains.

This invention also provides genes encoding the variable regions of said humanized heavy or light chain.

In addition, this invention provides expression vectors containing said genes and *E. coli* transformants containing said expression vectors.

This invention further provides pharmaceutical compositions comprising said humanized antibody, which may be administered in order to prevent HBV infection or to treat chronic hepatitis B.

Further features of the present invention will appear hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1a and FIG 1b comparatively depict the amino acid and nucleotide sequences of V_H regions (for Variable regions of Heavy chains) in a mouse monoclonal antibody KR127 and in two humanized antibodies of this invention,

FIG 2a schematically depicts a process for preparing HKR127HC(I) gene encoding the heavy chain of a humanized antibody of this invention,

FIG 2b schematically depicts a process for preparing HKR127HC(III) gene encoding the heavy chain of a humanized antibody of this invention,

FIG 3a and FIG 3b comparatively depict the amino acid and nucleotide sequences of V_L regions (for Variable regions in Light chain) in a mouse monoclonal antibody KR127 and in a humanized antibody of this invention.

FIG 4 schematically depicts a process for preparing HKR127KC(I) gene encoding a humanized antibody of this invention,

FIG 5a depicts an expression vector pCMV-HKR127HC containing a gene for heavy chain of the humanized antibody,

FIG 5b depicts an expression vector pKC-dhfr-HKR127 containing a gene for light chain of the humanized antibody,

FIG 5c depicts an expression vector pCMV-HKR127HC(III) containing a gene for heavy chain of the humanized antibody,

FIG 6a comparatively shows the binding affinities of a humanized antibody (HZKR127I) and a mouse monoclonal antibody (KR127), and

FIG 6b comparatively shows the binding affinities of a humanized antibody (HZKR127III) and a humanized antibody (HZKR127I).

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter, the present invention is described in detail.

This invention provides humanized antibodies specific for HBV surface antigen pre-S1, comprising humanized heavy and humanized light chains.

This invention also provides genes encoding the variable regions of said humanized heavy or light chain.

Said humanized heavy chain contains variable region which is derived from the V_H region of mouse KR127 antibody. The V_H region of mouse KR127 antibody is described by SEQ ID NO: 19, and the V_H region of the humanized antibody of this invention can be prepared by grafting the CDRs of mouse KR127 V_H region to homologous human immunoglobulin V_H region.

And said humanized light chain contains variable

region which is derived from the V_L region of mouse KR127 antibody. The V_L region of mouse KR127 antibody is described by SEQ ID NO: 22, and the V_L region of the humanized antibody of this invention can be prepared by grafting the CDRs of mouse KR127 V_L region to homologous human immunoglobulin V_L region.

In preferred embodiments, we screened human immunoglobulin that show the highest similarities of amino acid sequence to the heavy or light chain of the mouse monoclonal antibody KR127. In result, human immunoglobulin germ line genes DP7 and DPK12 were screened from GenBank database. DP7 shows the highest homology to the V_H region of mouse antibody KR127, while DPK12 is most similar to the V_L region of KR127.

The humanized antibodies of this invention can be produced from recombinant genes encoding humanized V_H region or V_L region. These genes are constructed by substituting CDRs of mouse KR127 for those of the human DP7 or DPK12 antibody. In constructing these genes, most of the amino acid residues corresponding to the humanized CDRs are derived from the CDRs of mouse antibody KR127. However, some mouse-derived CDRs residues are replaced by human counterparts, since their corresponding amino acid residues are expected not to be involved in the antigen binding (see FIG 1). In the same way, some human-derived amino acid residues for the non-CDR framework regions (FR) of variable

region are replaced with mouse counterparts, since it is expected that these FR residues may affect the conformation of CDRs.

Particularly, HKR127HCv(HZII) gene encoding a humanized V_H region was prepared by grafting the partial CDR1, 2, 3 and a FR residue (at position 72) of mouse KR127 heavy chain to the human DP7 gene (see FIG 1).

However, antibody expressed from HKR127HCv(HZII) gene did not show any significant level of binding capacity to corresponding antigen. To improve the HKR127HCv(HZII) gene, we also prepared HKR127HCv(HZI) gene and HKR127HCv(HZIII) gene which contain more mouse-derived codons than HKR127HCv(HZII) gene (see FIG 1).

HKR127HCv(HZI) contains CDR1, partial CDR2, and CDR3, and 11 FR residues of mouse KR127 V_H, while HKR127HCv(HzIII) contains the same mouse CDR codons and 2 mouse FR residues (see FIG 1).

To construct HKR127HC(I) gene encoding a full-length heavy chain of the humanized antibody of this invention, PCRs were conducted, in which template for amplification is either the HKR127HCv(HZII) gene or pRC/CMV-HC-HuS (KCTC 0229BP) containing the heavy chain leader sequence and the constant region sequence of human immunoglobulin heavy chain γ1.

Six pairs of oligonucleotides (SEQ ID NO: 1 and 2;

3 and 4; 5 and 6; 7 and 8; 9 and 10; and 11 and 12) were used as PCR primers (see FIG 2a).

The first five PCR products were brought to annealing reaction. Then, the DNA fragment containing the five PCR products was employed as a template of recombinant PCR wherein two primers described by SEQ ID NO: 1 and 10 were used. Another recombinant PCR was conducted to link the amplified 431-bp DNA fragment to DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 11 and 12). The recombinant PCR employed two primers described by SEQ ID NO: 1 and 12. The final 1431-bp PCR product, HKR127HC(I), encoding the heavy chain of a humanized antibody (HZKR127I) was introduced into pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127HC(I).

The primers are described in SEQ ID NO: 1 to 12 in SEQUENCE LISTING, and particularly, primer described by SEQ ID NO: 1 contains EcoRI sequence at the 5′ end, while primer described by SEQ ID NO: 12 does SalI sequence at the 3′ end.

The variable region in the HKR127HC(I) gene contains 11 mouse-derived FR residues at positions 12, 28, 30, 48, 67, 68, 70, 72, 74, 79 and 95 (see FIG 1). The heavy chain variable region has 87 FR residues, and the unmodified FR residues is 76. Thus, the amino acid sequence of the heavy chain variable FR of the

HKR127HC(I) gene is 87% homologous to that of human DP7 gene.

To more humanize the HZKR127(I), HZKR127(III) gene was constructed, which contains HKR127HCv(HZIII) gene with 2 mouse-derived FR residues at position 72 and 74 (see FIG 1).

To construct HKR127HC(III) gene encoding a full-length heavy chain of the humanized antibody of this invention, PCRs were conducted, in which template for amplification is either the HKR127HCv(HZII) gene or pRC/CMV-HC-HuS (KCTC 0229BP) containing the heavy chain leader sequence and the constant region sequence of human immunoglobulin heavy chain γ1 (see FIG 2b).

Four pairs of oligonucleotides (SEQ ID NO: 1 and 24; 25 and 26; 27 and 28; and 11 and 12) were used as PCR primers (see FIG 2b). The first three PCR products were brought to annealing reaction. Then, the DNA fragment containing the three PCR products was employed as a template of recombinant PCR wherein two primers described by SEQ ID NO: 1 and 28 were used. Another recombinant PCR was conducted to link the amplified 431-bp DNA fragment to DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 11 and 12). The recombinant PCR employed two primers described by SEQ ID NO: 1 and 12.

The final 1431-bp PCR product, HKR127HC(III), encoding the heavy chain of a humanized antibody

(HZKR127III) was introduced into pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127HC(III).

In a further embodiment, HKR127KCv(HZII) gene encoding a humanized V_L region was prepared by grafting the CDR1, CDR3 and partial CDR2 of mouse KR127 light chain to the human DPK12 gene (see FIG 3).

However, antibody expressed by using the HKR127KCv(HZII) gene did not show any significant level of binding capacity to corresponding antigen. To improve the binding capacity of HKR127KCv(HZII), we also prepared HKR127KCv(HZI) gene which contains more mouse-derived amino acid residues (see FIG 3) than HKR127HKCv(HZII) (see FIG 3).

To construct HKR127KC(I) gene encoding a full-length light chain of the humanized antibody of this invention, PCRs were conducted, in which template for amplification is either the HKR127KCv(HZII) gene or pKC-dfhr-HuS (KCTC 0230BP) containing the light chain leader sequence and the constant region sequence of human immunoglobulin light chain κ.

Three pairs of oligonucleotides (SEQ ID NO: 13 and 14; 15 and 16; and 17 and 18) were used as PCR primers (see FIG 4).

The first two PCR products were brought to annealing reaction. Then, the DNA fragment containing

the two PCR products was employed as a template of recombinant PCR wherein two primers described by SEQ ID NO: 13 and 16 were used. Another recombinant PCR was conducted to link the amplified 360-bp DNA fragment to DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 17 and 18). The recombinant PCR employed two primers which are described by SEQ ID NO: 13 and 18. The final 739-bp PCR product, HKR127KC(I), encoding the light chain of a humanized antibody (HZKR127I) was introduced into pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127KC(I).

The primers are described in SEQ ID NO: 13 to 18 in SEQUENCE LISTING, and particularly, primer described by SEQ ID NO: 13 contains HindIII sequence at the 5' end, while primer described by SEQ ID NO: 18 does SalI sequence at the 3' end.

The variable region FR of the HKR127KC gene contains 5 mouse KR127-derived codons (see FIG 3). The light chain has 83 FR residues, and the unmodified FR residues is 78. Thus, the amino acid sequence of the light chain variable FR of the HKR127KC gene is 94% identical to that of human DP7 gene.

In addition, this invention provides expression vectors containing genes encoding the humanized V_H or V_L region and provides *E. coli* transformants containing

said expression vector.

In other preferred embodiments, expression vectors are prepared, which contain the gene encoding the heavy or light chain of humanized antibody (see FIG 5a, 5b or 5c).

Particularly, two kinds of DNA fragment corresponding to humanized heavy chain was respectively obtained from the plasmids pHKR127HC(I) and pHKR127HC(III) by treatment of restriction enzymes, and then inserted into pRc/CMV (Invitrogen) to give expression vector pCMV-HKR127HC (see FIG5a) and pCMV-HKR127(III)HC (see FIG 5c), respectively.

In addition, DNA fragment encoding the humanized light chain was isolated from the pHKR127KC vector, and then introduced into pCMV-dfhr (KCTC 8671P) to construct expression vector pKC-dhfr-HKR127 (see FIG 5b).

E. coli strain DH5α was transformed with the expression vector pCMV-HKR127HC, pCMV-HKR127(III)HC or pKC-dhfr-HKR127. The resulting *E. coli* transformants containing pCMV-HKR127HC or pKC-dhfr-HKR127 were deposited in KCTC (Korean Collection for Type Culture) (Accession Number: KCTC 0531BP and KCTC 0529BP, respectively) on October 12, 1998. The *E. coli* transformant containing pCMV-HKR127(III)HC was deposited in KCTC (Accession Number: KCTC 0691BP, respectively) on November 15, 1999.

In another preferred embodiment, humanized antibodies specific for HBV surface antigen pre-S1 were expressed in animal cells and obtained from culture media of the cells. COS7 cells were transiently cotransfected with the expression vectors pCMV-HKR127HC and pKC-dhfr-HKR127, and the resulting transfected cells was cultured and the culture supernatant was used to characterize a humanized antibody HZKR127I of the present invention. COS7 cells were also cotransfected with the expression vectors pCMV-HKR127(III)HC and pKC-dhfr-HKR127, and the culture supernatant of transfected cells was used to characterize a humanized antibody HZKR127III.

This invention further provides pharmaceutical compositions containing said humanized antibody.

According to still other preferred embodiments, it was verified that HZKR127I and HZKR127III humanized antibodies of the present invention, showed almost same antigen-binding affinity when compared with mouse monoclonal antibody KR127 (see Table 1, 2 and FIG 6a, 6b).

The composition includes a therapeutically effective amounts of the humanized antibody against HBV antigen pre-S1, with/without a pharmaceutically acceptable delivery vehicle. Moreover, the

compositions may include other anti-hepatitis drug(s), such as anti-S monoclonal antibody or lamivudin.

The humanized antibody against HBV antigen pre-S1 may be formulated with a pharmaceutical vehicle or diluent for intravenous, subcutaneous, intramuscular administration. The pharmaceutical composition can be formulated in a classical manner using solid or liquid vehicles, diluents and additives appropriate to the desired mode of administration.

The humanized antibody of this invention may be administered in a dosage range of about 1 ~ 10 mg/kg, preferably 3 ~ 5 mg/kg, and may be administered once a week.

EXAMPLES

Practical and presently preferred embodiments of the present invention are illustrative as shown in the following Examples.

However, it will be appreciated that those skilled in the art, on consideration of this disclosure, may make modifications and improvements within the spirit and scope of the present invention.

Example 1: Preparation of gene encoding humanized heavy chain

In order to construct the humanized heavy chain variable region gene, first, we selected a human immunoglobulin heavy chain gene that shows the highest homology of amino acid sequence to the heavy chain variable region of the mouse monoclonal antibody KR127. As the result, a human immunoglobulin germ line gene DP7 was selected from GenBank database. Then, we constructed a humanized V_H region gene HKR127HCv(HZII) by DNA recombination techniques, which was based upon the comparison of the mouse KR127 V_H region with the human DP7 V_H region. Since the humanized heavy chain did not show significant antigen binding activity, we prepared HKR127HCv(HZI) gene encoding another V_H region in order to improve the HKR127HCv(HZII) gene (see FIG 1).

Particularly, the HKR127HCv(HZII) gene was constructed by grafting the V_H region of human DP7 gene with the partial CDR1, 2, and 3 and one FR residue at position 72 of mouse KR127 V_H region. It was assumed that the human CDRs and FR amino acid residues affected the antigen-binding affinity of the antibody.

Therefore, HKR127HCv(HZI) gene was constructed by PCR employing HKR127HCv(HZII) gene as a template.

On the other hand, a vector pRc/CMV-HC-HuS (Accession Number: KCTC 0229BP) was used to synthesize DNA sequence encoding human C_H region as well as heavy chain leader sequence, which is required in proper secretion of the heavy chain.

Finally, HKR127HC(I) gene encoding a humanized heavy chain was constructed by recombinant PCR for the annealing of the heavy chain leader sequence, HKR127HCv(HZI) gene, and the human C_H gene (see FIG 2a).

The primers in these PCRs are synthetic oligonucleotides described by SEQ ID NO: 1 to 12. PCR was performed by using Taq DNA polymerase, and its thermocycle was repeated 30 times, consisting of 1 minute at 94°C, 1 minute at 55°C, and then 1 minute at 72°C. Five pairs of oligonucleotides (SEQ ID NO: 1 and 2; 3 and 4; 5 and 6; 7 and 8; and 9 and 10) were used as PCR primers, and the five PCR products (113 bp; 96 bp; 120 bp; 78 bp; and 87 bp, respectively) were brought to annealing reaction. Then, the DNA fragments containing the five PCR products were employed as template of the recombinant PCR wherein primers described by SEQ ID NO: 1 and 10 were used. Another recombinant PCR was conducted to link the amplified 431-bp DNA fragment to 1015-bp DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 11 and 12). The recombinant PCR employed two primers described by SEQ ID NO: 1 and 12.

The final PCR product (HKR127HC(I), about 1431-bp) encoding a recombinant heavy chain of humanized antibody was introduced into the EcoRI-SalI site of pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127HC(I). The DNA sequence of the inserted gene was determined by dideoxynucleotide method.

To more humanize the HKR127HC(I), another humanized heavy chain gene, HKR127(III), which has much less number of mouse FR residues, was constructed.

To construct the HKR127HC(III), HKR127HCv(HZIII) gene was constructed by PCR employing HKR127HCv(HZII) gene as a template. On the other hand, a vector pRc/CMV-HC-HuS (Accession Number: KCTC 0229BP) was used to synthesize DNA sequence encoding human C_H region as well as heavy chain leader sequence, which is required in proper secretion of the heavy chain.

Finally, HKR127HC(III) gene encoding a humanized heavy chain was constructed by recombinant PCR for annealing of the heavy chain leader sequence, HKR127HCv(HZIII) gene, and the human C_H gene (see FIG 2b).

The primers in these PCRs are synthetic oligonucleotides described by SEQ ID NO: 24 to 28. PCR was performed by using Taq DNA polymerase, and its thermocycle was repeated 30 times, consisting of 1 minute at 94°C, 1 minute at 55°C, and then 1 minute at

72°C. Three pairs of oligonucleotides (SEQ ID NO: 1 and 24; 25 and 26; and 27 and 28) were used as PCR primers, and the three PCR products (179 bp; 141 bp; and 87 bp, respectively) were brought to annealing reaction. Then, the DNA fragments containing the three PCR products were employed as template of the recombinant PCR wherein primers described by SEQ ID NO: 1 and 28 were used. Another recombinant PCR was conducted to link the amplified 431-bp DNA fragment to 1015-bp DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 11 and 12). The recombinant PCR employed two primers described by SEQ ID NO: 1 and 12.

The final PCR product (HKR127HC(III), about 1431-bp) encoding a recombinant heavy chain of humanized antibody was introduced into the EcoRI-SalI site of pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127HC(III). The DNA sequence of the inserted gene was determined by dideoxynucleotide method.

Example 2: Preparation of gene encoding humanized light chain

In order to prepare humanized light chain containing variable region, we devised genes encoding

the light chain. First, we selected a human κ immunoglobulin gene that shows the highest homology of amino acid sequence to the light chain of the mouse monoclonal antibody KR127. As the result, a human κ immunoglobulin gene DPK12 was selected from GenBank database. Then, we constructed HKR127KCv(HZII) gene encoding a humanized V_L region by grafting CDR1, partial CDR2, and CDR3 and one FR residue at position 41 of the mouse KR127 V_L region to the human DPK12 V_L region. The resulting humanized V_L was not functional in antigen-binding. To improve the HKR127KCv(HZII) gene, we constructed HKR127KCv(HZI) gene encoding another V_L region (see FIG 3).

The HKR127KCv(HZI) gene was constructed by grafting the V_L region of human DPK12 antibody with a few FR residues and CDR1, CDR2 and CDR3 of mouse KR127 V_L (see FIG 3).

On the other hand, a vector pKC-dhfr-HuS (Accession Number: KCTC 0230BP) was used to synthesize DNA sequence encoding human C_L region as well as light chain leader sequence, which is required in proper secretion of the light chain.

Finally, HKR127KC(I) gene encoding a humanized light chain was prepared by recombinant PCR for the annealing of the PCR products, light chain leader sequence, the HKR127KCv(HZI) gene, and the human C_L gene (see FIG 4).

The primers in these PCRs are synthetic oligonucleotides described by SEQ ID NO: 13 to 18. The thermocycle of these PCRs was repeated 30 times, consisting of 1 minute at 94°C, 1 minute at 55°C, and 1 minute at 72°C. Two pairs of oligonucleotides (SEQ ID NO: 13 and 14; and SEQ ID NO: 15 and 16) were used as PCR primers, and the two PCR products (101 bp and 159 bp, respectively) were brought to annealing reaction. Then, the DNA fragments containing the two PCR products was employed as a template of recombinant PCR wherein primers described by SEQ ID NO: 13 and 16 were used. Another recombinant PCR was conducted to link the amplified 248-bp DNA fragment to 515-bp DNA fragment which was obtained by PCR using two primers (described by SEQ ID NO: 17 and 18). The recombinant PCR employed two primers described by SEQ ID NO: 13 and 18.

The final PCR product (HKR127KC(I), 736-bp) encoding a recombinant light chain of humanized antibody was introduced into the HindIII-SalI site of pBluescript SK(+) vector (Clontech), and the resulting vector was designated pHKR127KC(I). The DNA sequence of the inserted gene was determined by dideoxynucleotide method.

Example 3: Construction of expression vector containing the humanized heavy chain gene

The pHKR127HC(I) or pHKR127HC(III) plasmid of Example 1 was digested with SalI enzyme, and the both ends of the vector was made blunt using Klenow enzyme treatment. This DNA fragment was further digested with NotI enzyme to obtain the gene encoding humanized heavy chain.

On the other hand, pRc/CMV (Invitrogen) was cut with XbaI enzyme, and the ends of the vector was made blunt by treating with Klenow enzyme, and then digested with NotI.

The humanized heavy chain gene and the linearized vector were linked to give expression vector pCMV-HKR127HC or pCMV-HKR127(III)HC. The *E. coli* transformant containing pCMV-HKR127HC or pCMV-HKR127(III)HC was deposited in KCTC (Korean Collection for Type Culture) (Accession Number: KCTC 0531BP and KCTC 0691BP, respectively), and the expression vector pCMV-HKR127HC and pCMV-HKR127(III)HC is shown in FIG 5a and 5c, respectively.

Example 4: Construction of expression vector containing the humanized light chain gene

The pHKR127KC vector of Example 2 was digested with HindIII and ApaI enzymes, and the resulting fragment was inserted into HindIII-ApaI site of pCMV-dhfr (Accession Number: KCTC 8671P) to give expression vector pKC-dhfr-HKR127. The *E. coli* transformant containing pKC-dhfr-HKR127 was deposited in KCTC (Korean Collection for Type Culture) (Accession Number: KCTC 0529BP), and the expression vector pKC-dhfr-HKR127 is shown in FIG 5b.

Example 5: Expression of humanized antibody in COS7 cells

COS7 cells were maintained in DMEM (Gibco) supplemented by 10% calf serum at 37°C, under 5% CO_2 condition. The cells were inoculated in 100mm petri dishes, and then incubated at 37°C overnight.

To express a humanized antibody HZKR127I, 5 μg of pCMV-HKR127HC or pKC-dhfr-HKR127 was diluted with 800 μl of OPTI MEM I (Gibco), and 50 μl of Lipofectamin (Gibco) was also diluted with 800 μl of OPTI MEM I. These mixtures in 15-ml tubes were incubated at room temperature for 15 minutes or more. In the meantime,

COS7 cells were washed twice with OPTI MEM I.

OPTI MEM I (6.4 ml) was added to the DNA-Lipofectamin mixture, mixed well, and poured on the COS7 cells. After the cells were cultured in a CO_2 incubator for 72 hours, the medium was centrifuged, and the supernatant was concentrated by ultrafiltration kit. The concentration of antibody was determined by Sandwich ELISA using anti-human IgG and anti-human IgG-HRP (horseradish peroxidase) conjugate.

To express and obtain a humanized antibody HZKR127III, the same protocol was repeated except using pCMV-HKR127(III)HC instead of using pCMV-HKR127HC.

Example 6: Binding activity of humanized antibody to HBV surface antigen pre-S1

We prepared HBV surface antigen pre-S1 (amino acid residue 1-56; Kim and Hong, Biotechnology Letters, 17:871-876, 1995) and 1 μg of the purified pre-S1 was coated on each well in microplates. After addition of 0, 0.25, 0.5, 1, 2, 3, 4, 5, 7.5, 10, 20, or 40 ng of the humanized antibodies prepared in Example 5, indirect ELISA was performed, in which secondary antibody was Fc-specific anti-human IgG-HRP conjugate. The binding activities of the antibodies were determined by measuring OD at 492 nm.

Purified mouse KR127 antibody was used as a control, and ELISA of KR127 antibody was conducted using Fc-specific anti-mouse IgG-HRP conjugate as a secondary antibody. The result is presented in Table 1 and 2.

Table 1.

Binding activity of KR127 and HZKR127I to HBV surface antigen pre-S1 (OD at 492 nm)

Amount (ng) / Antibody	0	0.25	0.5	1	2	3	4	5	7.5	10	20	40
KR127	0.09	0.12	0.15	0.20	0.30	0.36	0.43	0.54	0.60	0.80	1.16	1.64
HZKR127I	0.09	0.12	0.17	0.26	0.35	0.43	0.60	0.71	0.79	1.12	1.48	1.77

Table 2.

Binding activity of HZKR127I and HZKR127III to HBV surface antigen pre-S1 (OD at 492 nm)

Amount (ng) / Antibody	0	0.25	0.5	1	2	3	4	5	7.5	10	20	40
HZKR127I	0.06	0.19	0.25	0.58	0.65	0.75	0.86	1.02	1.25	1.39	1.95	2.07
HZKR127III	0.06	0.20	0.37	0.60	0.87	1.10	1.24	1.37	1.65	1.89	2.04	2.10

Example 7: Antigen-binding affinity of humanized antibody to HBV surface antigen pre-S1

Antigen-binding affinity to HBV surface antigen

pre-S1 was assayed by competitive ELISA method(Ryu et al., J. Med. Virol., 52:226, 1997).

Binding reactions between the pre-S1 antigen ($1 \times 10^{-7} \sim 1 \times 10^{-12}$ M) and the humanized antibody of Example 5 (5 ng), or between the antigen ($1 \times 10^{-7} \sim 1 \times 10^{-12}$ M) and control antibody KR127 (5 ng), were performed at 37°C for 2 hours. Then the reaction mixtures were added to 96-well microplates coated with the 250 ng of antigen pre-S1.

FIG 6a shows the affinity of two kinds of antibodies. It was confirmed that the binding affinity of the humanized antibody HZKR127I is almost same as that of the mouse antibody KR127 (7×10^{7} M^{-1}).

FIG 6b shows the affinity of HZKR127III compared with that of HZKR127I. The affinity of HZKR127III (5×10^{7} M^{-1}) was not much different from that (7×10^{7} M^{-1}) of HZKR127I.

INDUSTRIAL APPLICABILITY

As shown above, the present invention provides humanized antibody against HBV surface antigen pre-S1, which shows similar level of binding affinity when compared with mouse monoclonal antibody, whereas immunogenicity of the humanized antibody is remarkably reduced. Thus, the humanized antibody of the present

invention may be useful for the prevention of HBV infection and for the treatment of hepatitis B.

Those skilled in the art will appreciate that the conceptions and specific embodiments disclosed in the foregoing description may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present invention. Those skilled in the art will also appreciate that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended claims.

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Hong Hyo-Jeong
KIT Apt. 15-401, #237 Gajeong-dong, Yusong-ku, Taejon 305-350,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: ***Escherichia coli* DH5α /pCMV-HKR127HC**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0531BP**
II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION	
The icroorganism identified under I above was accompanied by: [x] a scientific description [ ] a proposed taxonomic designation (Mark with a cross where applicable)	
III. RECEIPT AND ACCEPTANCE	
This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **October 12 1998**	
IV. RECEIPT OF REQUEST FOR CONVERSION	
The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on	
V. INTERNATIONAL DEPOSITARY AUTHORITY	
Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority or of authorized official(s): PARK Yong-Ha, Director Date: **October 17 1998**

BUDAPEST TREATY ON THE INTERNATIONAL RECOGNITION OF THE DEPOSIT OF MICROORGANISMS FOR THE PURPOSE OF PATENT PROCEDURE

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: HONG, Hyo Jeong
KIT Apt. 15 401, #237, Kajeong-dong, Yusong-ku, Taejon 305-350,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM

Identification reference given by the DEPOSITOR:	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY:
Escherichia coli **DH5@/pCMV-HKR127(III)HC**	**KCTC 0691BP**

II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION

The microorganism identified under I above was accompanied by:
[x] a scientific description
[ ] a proposed taxonomic designation
(Mark with a cross where applicable)

III. RECEIPT AND ACCEPTANCE

This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **November 15 1999.**

IV. RECEIPT OF REQUEST FOR CONVERSION

The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on

V. INTERNATIONAL DEPOSITARY AUTHORITY

Name: Korean Collection for Type Cultures

Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB)
#52, Oun-dong, Yusong-ku,
Taejon 305-333,
Republic of Korea

Signature(s) of person(s) having the power to represent the International Depositary Authority of authorized official(s):

Bae K. S.

BAE, Kyung Sook, Director
Date: **November 18 1999**

INTERNATIONAL FORM

RECEIPT IN THE CASE OF AN ORIGINAL DEPOSIT

issued pursuant to Rule 7.1

TO: Hong Hyo-Jeong
KIT Apt. 15-401, #237 Gajeong-dong, Yusong-ku, Taejon 305-350,
Republic of Korea

I. IDENTIFICATION OF THE MICROORGANISM	
Identification reference given by the DEPOSITOR: ***Escherichia coli* DH5α /pKC-dhfr-HKR127**	Accession number given by the INTERNATIONAL DEPOSITARY AUTHORITY: **KCTC 0529BP**
II. SCIENTIFIC DESCRIPTION AND/OR PROPOSED TAXONOMIC DESIGNATION	
The icroorganism identified under I above was accompanied by: [x] a scientific description [ ] a proposed taxonomic designation (Mark with a cross where applicable)	
III. RECEIPT AND ACCEPTANCE	
This International Depositary Authority accepts the microorganism identified under I above, which was received by it on **October 12 1998**	
IV. RECEIPT OF REQUEST FOR CONVERSION	
The microorganism identified under I above was received by this International Depositary Authority on and a request to convert the original deposit to a deposit under the Budapest Treaty was received by it on	
V. INTERNATIONAL DEPOSITARY AUTHORITY	
Name: **Korean Collection for Type Cultures** Address: Korea Research Institute of Bioscience and Biotechnology (KRIBB) #52, Oun-dong, Yusong-ku, Taejon 305-333, Republic of Korea	Signature(s) of person(s) having the power to represent the International Depositary Authority or of authorized official(s): PARK Yong-Ha, Director Date: **October 17 1998**